Relationship between magnitude of perceptual velocity and magnetoencephalogram

K. Amano[1], T. Takeda[1,2,3], T. Owaki[3], and I. Kuriki[1,3]

[1] *Dept. of mathematical engineering and information physics, Graduate School of Engineering, University of Tokyo, Tokyo, 113-8656, Japan;* [2] *Dept. of Complexity Science and Engineering, Graduate School of Frontier Science, University of Tokyo, Tokyo, 113-0033, Japan;* [3] *Core Research for Evolutional Science and Technology (CREST), Japan Science and Technology Corporation (JST), Saitama, Japan*

1 Introduction

Electrophysiological data from animals and humans suggest that there are direction selective cells in area MT/V5 and its neighboring area MST [1]. It is estimated that these areas are related to motion perception. However, there exist a number of brain areas responsive to motion, presumably working as a network, and their properties are still not clear.

Adaptation in motion perception is a phenomenon in which perceptual velocity decreases when subjects are seeing a constantly moving stimulus (adaptation stimulus). If we gaze at a static target in adapted state, it will appear to move in the opposite direction of the adaptation stimulus. This is called motion after-effect (MAE). Many psychophysical studies related to MAE have been reported for many years. For example, relationship between the perceptual velocity or duration of MAE and the velocity or spatial frequency of adaptation stimulus were studied in detail [2, 3].

In recent years, there are some studies related to human motion perception using non-invasive functional brain measurement. In an fMRI study, Tootell et al. reported an activity in area MT when subjects perceived MAE [4]. Ahlfors et al. estimated motion sensitive areas involved in processing changes in the direction of motion using both MEG and fMRI. This study revealed motion related activity in areas MT+ (area MT and MST), a region near the posterior end of the superior temporal sulcus (pSTS), V3A, and V1/V2 [5].

Investigating the mechanism of adaptation in motion perception is a very important problem to know how people perceive the motion after-effect. However, only a few studies have reported relationships between visual motion perception and neural activity in the human brain. So we investigated the effect of adaptation on MEG responses and analyzed the responses commonly found in motion reversal stimulus and MAE stimulus conditions. We also performed psychophysical experiments to measure the subjective velocity before and after the stimulus change in velocity.

2 Methods

2.1 Subjects

Four subjects (all male, aged 22-33, normal or corrected-to-normal visual acuity) participated in this study. One of the subjects was left-handed. They were informed of experimental procedures of present study.

2.2 Visual stimuli

The stimuli were made using VSG2/3 stimulus generator (Cambridge Research System) and presented on a screen (40 deg x 30 deg) at a distance of 140 cm from subjects by a liquid crystal projector. The visual motion stimulus was 10°in diameter, consisting of concentric, contracting and expanding half rings centered at the fixation point. The stimulus motion was terminated or reversed after continuous motion for 5s (adaptation) or 0.6s (no-adaptation). The velocity of these stimuli was determined after psychophysical measurement, in which the best velocity of adaptation stimulus for motion after effect was examined. In this measurement, the velocity of test stimulus was adjusted to null the MAE and the physical velocity of the stimulus when MAE is nulled was regarded as the intensity of MAE. The strongest effect of adaptation stimulus was provided at 2.8 degree per second (dps). Both mean luminance of the stimuli and luminance of background were 50 cd/m^2. The contrast of the half ring was set at 5% to specifically enhance the responses in area MT+ relative to area V1 [7].

2.3 MEG data acquisition

The MEG data were recorded with a whole-head 64-channel dc-SQUID device (CTF, Canada) in a magnetically shielded room. Trials were recorded with sampling rate 625Hz with no on-line filtering from –200ms to +800ms relative to stimulus onset.

Epochs containing blinking artifacts were rejected. For each subject, 100 epochs were averaged. The averaged responses were low-pass filtered at 40Hz and high-pass filtered at 1Hz. The trigger for MEG measurement was set on the moment of change in velocity of stimulus.

Experiment1: The responses in adapted state were recorded. The stimuli were contracting for 30s (adaptation phase) and then repeated the cycle1 (contracting for 5s and expanding for 1s) or cycle2 (contracting for 5s and terminated for 1s). In cycle2, all subjects reported that they perceived motion after-effect.

Experiment2: The responses in non-adapted state were recorded. The stimuli were repeated cycle3 (contracting for 0.6s, expanding for 1s and terminated for 4s) or cycle4 (contracting for 0.6s and terminated for 5s).

2.4 Psychophysical measurement

We also performed the psychophysical experiments using the same subjects. The experimental conditions were the same as those of MEG study. The purpose of this study is to measure the perceptual velocity before and after velocity change of the stimulus in both adapted and non-adapted state.

3 Results

3.1 MEG responses

Figure 1 shows typical time charts of visual evoked magnetic fields (TO) in response to the change in the direction of motion (cycle1 and cycle 3). Both right and left hemifield conditions are plotted. Prominent responses peaked at two latencies. In both adapted and non-adapted conditions, the first latencies are between 210ms and 230ms, and the second latencies are between 260ms and 280ms. Figure 2 shows maps of the measured magnetic field at the first peak latencies in conditions of cycle1 and cycle2. In both right and left hemifield conditions, strong MEG responses were recorded in the right hemisphere.

3.2 Psychophysical measurement

Subjective velocities before and after the moment of velocity change are shown in Figure 3. The velocity before the change in velocity of stimulus was slower in adapted state than those in non-adapted state by about 0.5dps. The velocities after the motion termination in adapted state can be estimated as the intensity of the MAE. On the other hand, the subjective velocities after the motion reversal were lower in adapted state than in no-adapted state. These results are consistent with the previous study [6].

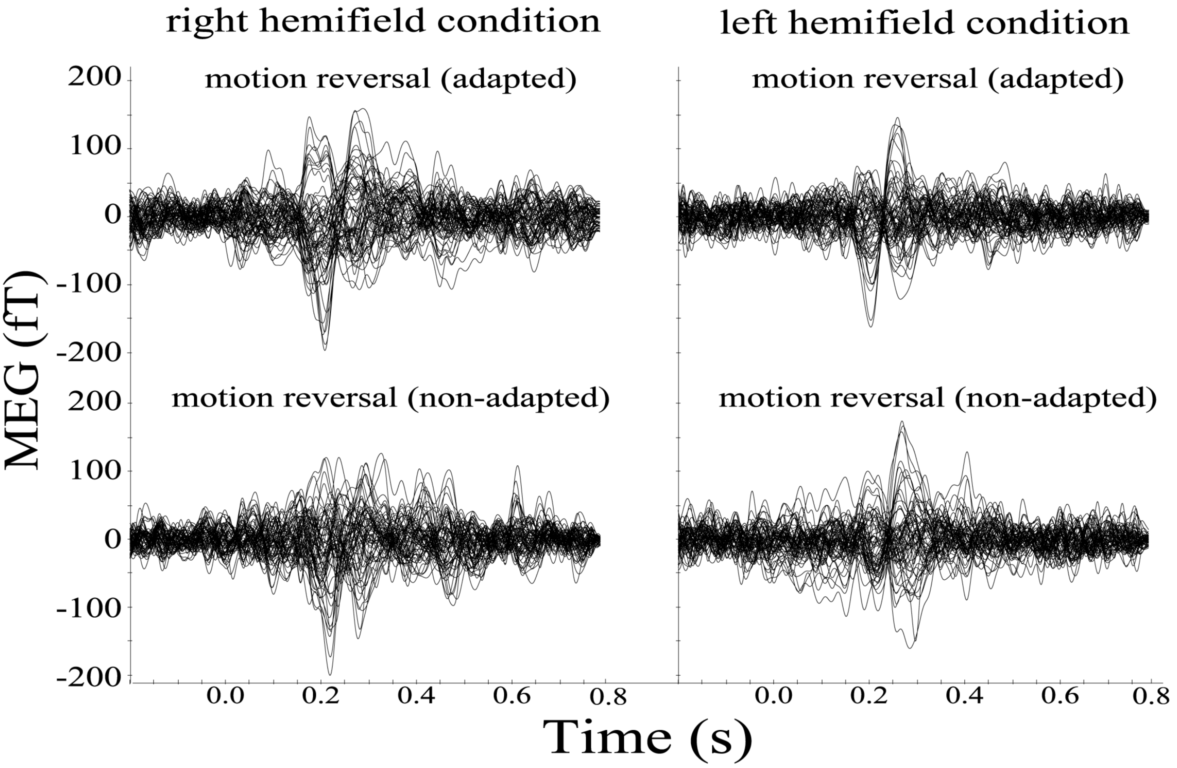

Figure 1: *The time course of averaged waveforms of the magnetic fields evoked by motion reversal in both adapted and non-adapted state. Right and left hemifield conditions are plotted.*

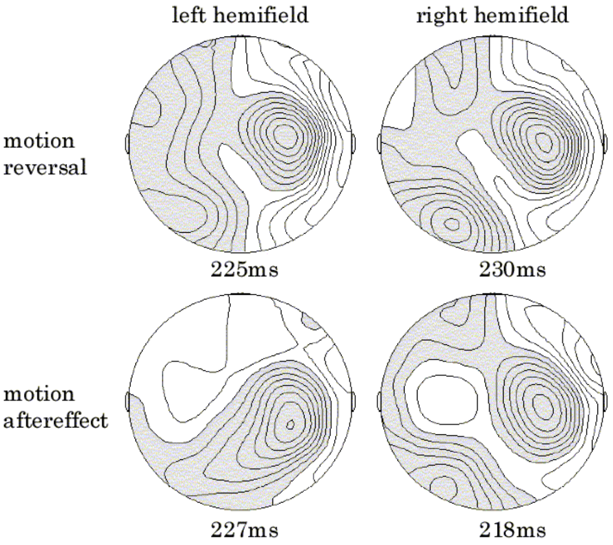

Figure 2: *Iso-magnetic field evoked by motion reversal stimuli and motion after-effect stimuli at the first peak latencies*

4 Discussion

In both right and left hemifield conditions of right-handed subjects, the MEG activity peaked at 180ms - 230ms. In the magnetic fields of each experimental condition, larger responses were recorded from the right hemisphere. The left-handed subject showed the opposite tendency. This result suggests the possibility that visual motion related information is integrated in the inferior hemisphere after processing in area MT of contralateral hemisphere to the stimulus.

Motion reversal stimulus in adapted or non-adapted state and motion termination stimulus in adapted state (subjects perceived MAE) evoked similar MEG responses. This suggests the possibility that processing in MAE perception share the same mechanism with the simple motion reversal. There is good possibility that these responses include area MT, but we could not identify the dipole with high goodness of fit using one dipole model. This may result from the fact that many cortical areas are activated at the same latencies in motion perception.

Figure 4 shows Root mean square (RMS) values of right or left 32 channel data in response to the motion reversal stimulus. Solid lines indicate the values in adapted state and broken lines indicate the ones in no-adapted state. Responses in adapted states are larger especially in the first peak latencies around 220ms. According to psychophysical measurement, subjective velocity after the motion reversal was lower in adapted state than in no-adapted state. However, MEG intensity was larger in adapted state.

It is known that after exposure to prolonged movement in one direction (adaptation to motion), the firing rate of cells sensitive to the movement becomes smaller [2]. But our result does not necessarily correspond with this previous study. The increase of MEG intensity by adaptation suggests two possibilities. Firstly, it can be thought that synchronization of the firing of each cells increase even though firing rates of each cells decrease. It is not clear that increase in the synchronization of firing leads to the strong MEG intensity, but it could be possible that the timing of firing in motion selective cells come to be uniform as adaptation progresses. Secondly, there could be the possibility of the existence of some cells that increase the firing rate during adapted state. The direction selective cells that are sensitive to the opposite direction to adapted direction increase their firing rate. This model assuming the increase of firing rate corresponds with the study that there are some cells that do not decrease their firing rate [2]. According to this model, adaptation in motion perception does not mean a phenomenon that can be compared to the fatigue of muscles but more positive balancing mechanism. This model can clearly explain the increase of MEG intensity by adaptation.

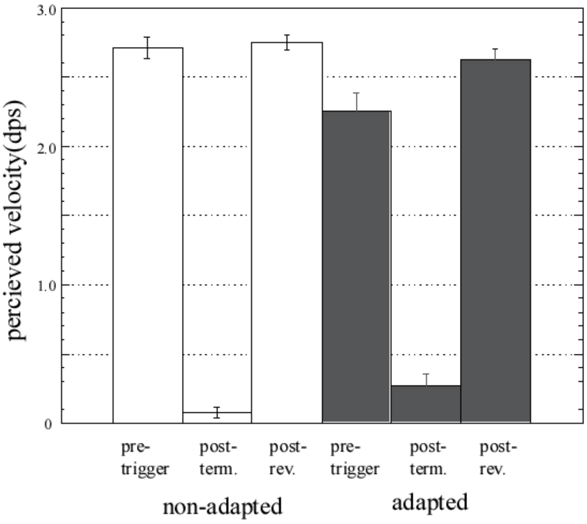

Figure 3: *Subjective velocity before and after the velocity change of stimulus.*

At present, it is difficult to explain the contradiction between subjective velocity and RMS value in motion reversal. Effect of adaptation on each visual area, such as V1, V2/V3 and MT, is the primary problem to be solved. We think that one effective way to do this task is applying SSP to our data [8].

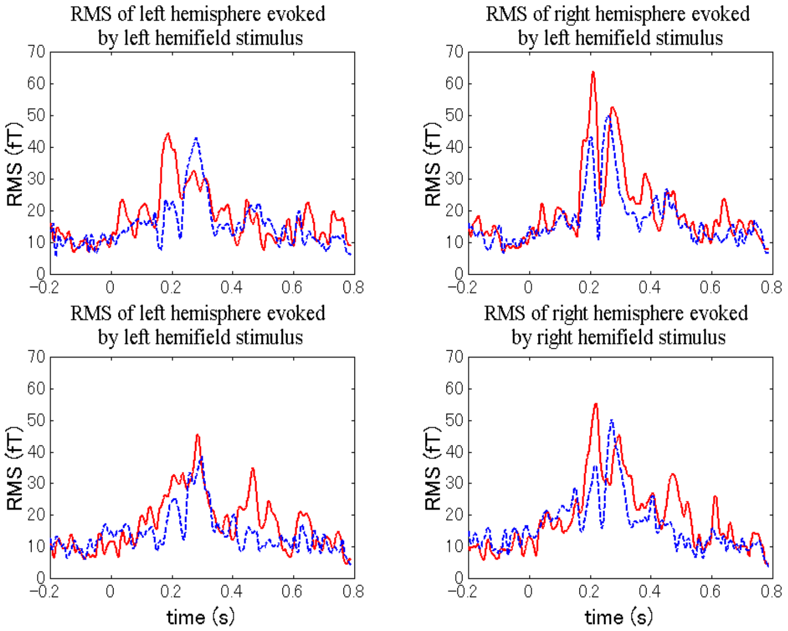

Figure 4: *Root Mean Square (RMS) values for motion reversal stimuli in adapted and no-adapted state. Solid lines (red) and broken lines (blue) indicate adapted state and no-adapted state, respectively.*

More experiments in the conditions of other stimulus velocities are needed to consider about the relationship between subjective velocity and MEG more precisely.

5 Conclusion

In both right and left hemifield conditions, large MEG responses were observed in the right hemisphere of right-handed subjects. The left-handed subject showed the opposite tendency. This result suggests the possibility of higher neural processing related to motion perception is dominant in the inferior hemisphere. Also it was shown that the MEG intensity increases by adaptation. There could be some possibility that motion adaptation does not simply mean a decrease of activation in the motion related cortex.

Acknowledgements

This work was supported by JST (CREST).

References

1. S. Zeki, J.D.G. Watson, C.J. Lueck, K.J. Friston, C. Kennard, and R.S.J. Frackowiak "A Direct Demonstration of Functional Specialization in Human Visual Cortex", *The Journal of Neuroscience*, **11**(3), 641-649, 1991.
2. S. Anstis, F.A.J. Verstraten, and G. Mather "The motion aftereffect", *Trends in Cognitive Science* **2**(3), 111-116, 1998.
3. H. Ashida and N. Osaka "Difference of spatial frequency selectivity between static and flicker motion aftereffects", *Perception* **23**, 1313-1320, 1996.
4. R.B.H. Tootell, J.B. Reppas, A.M. Dale, R.B. Lock, M.I. Sereno, R. Malach, T.J. Brandy, and B.R. Rosen "Visual motion aftereffect in human cortical area MT revealed by functional magnetic resonance imaging", *NATURE* **375**, 139-141, 1995.
5. S.P. Ahlfors, G.V. Simpson, A.M. Dale, J.W. Belliveau, A.K. Liu, A. Korvenoja, J. Virtanen, M. Huotilainen, R.B.H. Tootell, H.J. Aronen, and R.J. Ilmoniemi, "Spatio-temporal Activity of a Cortical Network for Processing Visual Motion Revealed by MEG and fMRI", *The American Physiological Society*, 1999.
6. P. Thompson, "Velocity after-effects: The effects of adaptation to moving stimuli on the perception of subsequently seen moving stimuli", *Vision Research* **21**, 337-345, 1981
7. R.B.H. Tootell, J.B. Reppas, K.K. Kwong, R. Malahc, R.T. Born, T.J. Brady, B.R. Rosen, and J.W. Belliveau "Fuctional analysis of human MT and Related Visual Cortical Areas Using Magnetic Resonance Imaging", *The Journal of Neuroscience* **15**(4), 3215-3230, 1995.
8. C.D. Tesche, M.A. Uusitalo, R.J. Ilmoniemi, M. Huotilainen, M. Kajola, and O. Salonen "Signal-space projections of MEG data characterize both distributed and well-localized neuronal sources", *Electroencephalography and clinical Neurophysiology* **95**, 189-200, 1995.